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PROBLEMS IN MEASURING TEAM EFFECTIVENESS.(U)
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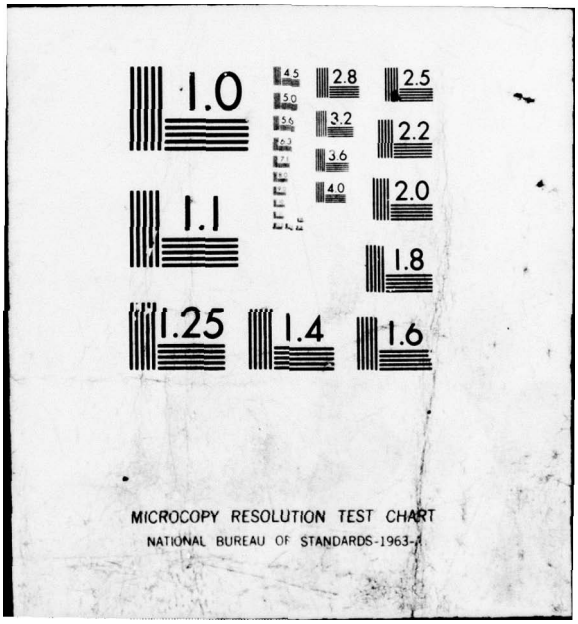
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(9) Professional Paper 2-78
(14) HumRRO-PP-2-78

HumRRO

B.S.

(6) Problems in Measuring Team Effectiveness

(10) Albert L. Kubala

(12) 12p.

(15) DAHC19-75-C-0025

Presentation at the
19th Conference of the
Military Testing Association
San Antonio, Texas October 1977

HUMAN RESOURCES RESEARCH ORGANIZATION
300 North Washington Street • Alexandria, Virginia 22314

(11) January 1978

Prepared for

U.S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, Virginia 22333

405260

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Professional Paper 2-78	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) "Problems in Measuring Team Effectiveness"		5. TYPE OF REPORT & PERIOD COVERED Professional Paper 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Albert L. Kubala		8. CONTRACT OR GRANT NUMBER(s) DAHC 19-75-C-0025 new
9. PERFORMING ORGANIZATION NAME AND ADDRESS Human Resources Research Organization (HumRRO) 300 North Washington Street Alexandria, Virginia 22314		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue Alexandria, Virginia 22314		12. REPORT DATE January 1978 13. NUMBER OF PAGES 9
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Research performed by HumRRO Western Division/Ft. Hood, under Project HOOD, "Human Factors Research in Military Organizations and Systems".
Presented at the 19th Conference of the Military Testing Association, San Antonion, Texas, October 1977.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Team Effectiveness
Measures of Effectiveness (MOE)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Considerable effort has gone into the development of techniques for measuring the job effectiveness of individuals. As a result, procedures are highly developed, documented, and validated. Comparable effort has not been devoted to the development of means of evaluating the performance of teams (i.e., two or more individuals associated in work or activity directed toward a common goal). This paper examines the problems associated with measuring team effectiveness employing the tank crew as the primary medium for discussion. The

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literature is reviewed and current approaches to measuring team effectiveness in military settings are examined. Topics discussed are: (a) defining effectiveness, (b) distinguishing between true team tasks and tasks which are a simple summation of individual efforts, (c) one-sided vs two-sided engagement simulations in measuring effectiveness, (d) process vs outcome measures, and (e) requirements for and use of available resources. It is concluded that gunnery is the only tank crew function (parts of which might qualify as team tasks) that is currently being assessed, and that these measures are of questionable reliability.

PREFATORY NOTE

This paper is based on a presentation given at the 19th Conference of the Military Testing Association, October 17-21, 1977, at San Antonio, Texas. The conference was hosted by the Air Force Human Resources Laboratory and the Air Force Occupational Measurement Center.

Dr. Albert L. Kubala, the paper's author, is a Senior Staff Scientist in HumRRO's Western Division. He is presently heading a team of HumRRO scientists conducting research for the Department of the Army at Fort Hood, Texas. The information presented in this paper was developed in the course of research accomplished in Project HOOD, "Human Factors Research in Military Organizations and Systems."

PROBLEMS IN MEASURING TEAM EFFECTIVENESS

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Background

Borrowing heavily on characteristics of teams described by Glaser, Klaus, and Egerman,[2] as well as Hall and Rizzo,[3] Wagner, Hibbits, Rosenblatt, and Schulz[4] define team training as:

SLIDE 1

> The training of two or more individuals who are associated together in work or activity. The team is relatively rigid in structure and communication pattern. It is goal- or mission-oriented with the task of each team member well-defined. The functioning of the team depends upon the coordinated participation of all or several individuals. The focus of team training and feedback is on team skills (e.g., coordination), activities and products.

It can be seen from the implied definition of a team, that a team could be composed of anything from a two-man crew to a unit of almost any size. However, most of the literature dealing with teams has considered relatively small units such as those associated with one piece of equipment, such as a tank or aircraft, or at most, a platoon with a single objective or mission. Wagner, et al., further points out that, while the military services conduct up to 90% of their training in the operational commands, most training research has been focused on individual training in institutional settings. For example, in FY 1974, the Army Research Institute for the Behavioral and Social Sciences (ARI) initiated the largest program of unit training and evaluation research in history. Yet, only 11% of the human resources budget was spent in this area. Judging from the literature, the

[1] This work was performed under Contract DAHC19-75-C-0025 to the US Army Research Institute for the Behavioral and Social Sciences (ARI). Dr. Charles O. Nystrom was the Contract Monitor.

[2] R. Glaser, D.J. Klaus, and K. Egerman. *Increasing team proficiency through training: 2. The acquisition and extinction of a team response*, Technical Report AIR B64-5/62, American Institutes for Research, May 1962.

[3] E.R. Hall and W.A. Rizzo. *An assessment of US Navy tactical team training: Focus on the trained man*, TAEG Report No. 18, Training Analysis and Evaluation Group, March 1975.

[4] H.Wagner, N. Hibbits, R.D. Rosenblatt, and R. Schulz. *Team training and evaluation strategies: State-of-the-art*, Technical Report 77-1, Human Resources Research Organization, Alexandria, Virginia, February 1977.

resources devoted to this area by the other military services has been roughly comparable. This lack of emphasis seems strange in view of the fact that most fighting has been, and will continue to be done by teams. It now seems critical that we determine how well our teams do function, for as MG Gorman has stated, we must:

SLIDE 2

> . . . train the Army to win on the first battlefield of the next war against an enemy that outnumbers us, against an enemy whose weapons will be as good as or nearly as good as those we possess. . . .[1]

In other words, we can ill afford any but the most effective fighting teams. And, to ensure maximum effectiveness, Measures of Effectiveness (MOE) must be derived so that commanders can evaluate their own teams, discover deficiencies, and take corrective measures.

Our HumRRO contingent at Fort Hood became involved in this area when we were asked to determine what set of MOE were currently being employed to evaluate tank crews, and to determine what additional research was needed to ensure a comprehensive evaluation capability. We soon found that for all practical purposes, the only MOE in current use are scores on Table VIII, otherwise known as the Tank Crew Qualification Course.[2] For those of you unfamiliar with Table VIII, it should suffice for the moment to know that it is a live-fire gunnery exercise, where crews are scored on both hit accuracy and times to engage targets. Looking further at this MOE, we were surprised to find that the reliability of Table VIII scores has apparently never been determined, and that many question its validity as a predictor of combat effectiveness. We wondered why no other MOE were in use, and why one which was somewhat suspect was in general use. We wondered what the problem(s) was(were). Therefore, we decided that the next step should be a study of the problems associated with the development and use of team evaluations, which is the subject of this paper.

I doubt that anything I say will really be new to any of you. My purpose in presenting this paper is simply to re-focus your collective attention on these problems. I feel that the areas of team training and evaluation, especially evaluation, have been much neglected. Hopefully, this presentation will generate some interest in and lead some of you toward, solutions for some of the problems I will discuss. We have painstakingly developed procedures for building training programs and evaluating individuals. We have out inter-service procedures for instructional systems development,[3] and are now, in the Army, developing individual Skill Qualification Tests (SQTs). These tests will be designed to test actual job performance as well as knowledge, and successful performance will be a prerequisite for both retention and/or promotion. However, we have no similar procedures for either curriculum development or evaluation of teams, and they are sorely needed.

[1] W.E. DuPuy and P.F. Gorman. "TRADOC mission and resources briefing," transcript from TV tape, US Army Training and Doctrine Command, Fort Monroe, Virginia.

[2] J.A. Larson, W.K. Earl, and V.A. Henson. *Assessment of US tank crew training*, TCATA Test Report No. FM 331, Final Report (23 March 75 - 13 March 76), HQ, TRADOC Combined Arms Test Activity, Fort Hood, Texas, July 1976.

[3] TRADOC PAM 350-30. *Interservice procedures for instructional systems development*, US Army Training and Doctrine Command, Fort Monroe, Virginia, 1 August 1975.

Problems

The particular problems which I have chosen for further elaboration are shown in the next slide.

SLIDE 3

- Defining Effectiveness
- Defining Team Effectiveness
- Problems With Numbers
- Reliability
- Evaluation Strategies
- Resources

Defining effectiveness. Historically, MOE were derived to ensure the quality of newly developed hardware. For one of our simplest weapons—the rifle—accuracy was the original MOE. Somewhat later, rate of fire was added as an MOE. Still later, it was realized that a highly accurate rapid fire weapon was of little value unless it were completely functional. Therefore, the concept of "availability" came into being as an MOE, and was measured by such things as Mean Time Between Failure (MTBF) and Mean Time to Repair (MTTR). However, the primary reason for the proliferation of MOE was the recognition that effectiveness was mission-dependent. For example, the weapon characteristics desirable for a sniper rifle are quite different from those required for a weapon designed primarily for suppression. In selecting a rifle, a sniper would be primarily interested in accuracy and range, but would not be too concerned about rate of fire. On the other hand, the soldier with the suppression mission would be very concerned with rate of fire, but not too concerned with accuracy.

An actual example from history serves to further illustrate the problems in defining effectiveness and the necessity to consider the mission in selecting MOE. In the early phases of WWII, a great many British merchant vessels were damaged or even destroyed by aircraft attacks. As a consequence, merchant vessels were equipped with antiaircraft guns and crews. After a period of time it was discovered that only 4% of the attacking enemy aircraft were actually shot down. This led some to conclude that the systems were ineffective on ships and could be better employed elsewhere, where kill rates were higher. Employing this MOE, the decision seemed inevitable. However, further examination of the data revealed that the antiaircraft fire greatly reduced the lethality of the enemy attack. In fact, the inclusion of antiaircraft weapons virtually halved the probability that a ship would be sunk. Viewed in this light, the systems were considered highly effective. In other words, the selection of the wrong MOE, or the exclusion of critical MOE, can lead to the wrong decision about effectiveness.

One further point needs to be emphasized. Training authorities and evaluators are not generally interested in the same kinds of MOE as hardware developers. The hardware is developed and fielded long before they get into the act. They must train personnel to use the equipment as it is, and must evaluate the effectiveness of the combination of the man and machine system. It matters little if a bench-fired weapon places 100 consecutive rounds within a 6-inch circle at 1000 meters, if, a typical user cannot hit a stationary enemy at 50 meters when employing the weapon. When evaluating training or unit readiness, the mission to be accomplished must be considered and the criteria of success must be set realistically in terms of the potential for man/machine effectiveness. Unfortunately, written guidance for the evaluator to aid him in selecting or developing MOE is nil.

Defining team effectiveness. One of the major problems associated with the evaluation of team effectiveness has been the inability of investigators to agree on what differentiates team and individual tasks. Most investigators agree that it is wasteful of effort to measure performance in a team context when the performance is actually nothing more than an aggregate of individual performances. Individual job skills can almost always be measured more easily, completely and cost effectively through individual job performance tests. It is felt that measurement of performance in a team context should be reserved for only those tasks which are truly team tasks; that is, *tasks which require cooperation or coordination to the extent that skills must be practiced in a team situation in order to be optimized.*

Hall and Rizzo characterized tasks performed by teams as being in either "established" or "emergent" situations. In established task situations, the sequence of task performance and the activities involved can be almost completely specified. Also, the assignment of task functions among team members and the equipment they operate are virtually fixed. In emergent situations, decision-making, problem-solving and sharing come to the forefront. The sequence of operations is not fixed, and the allocation of functions is variable. Hall and Rizzo essentially conclude that tasks performed in established situations are not really team tasks. Rather, overall task performance is simply the sum of the performances of the individual team members. Therefore, tasks performed in established situations should not be evaluated in a team context.

Unfortunately, in discussing various tasks with knowledgeable people in the armor community, I have found little agreement as to which tasks are established and which are emergent. For example, some have told me that firing on the move is definitely a team task. The advocates of this position point to the need for precise timing between the driver, who must find a level spot at exactly the right moment and maintain his direction, and the rest of the crew. Others feel that any accomplished driver does this habitually, and that so long as all crew members are individually competent, that the procedures employed ensure the proper conduct of the engagement. I will not attempt to defend either of these positions; I mentioned this example only to illustrate the differences of opinion I have encountered in trying to differentiate team performances from performances which are merely an aggregate of individual performances.

Problems with numbers. In attempting to fully describe the job situations of a tank crew in gunnery, Kraemer, Boldovici, and Boycan[1] derived a set of 11 classes of conditions or variables that could affect a crew's capability to successfully engage targets. Some examples of these classes and the number of levels identified for each class are shown in the following slide. The term "levels" refers to subclasses with a main class. If a tank gunnery objective were written for all possible combinations of levels, a total of 1,679,616 objectives would result. However, a large number of combinations are unrealistic (e.g., a moving bunker) and were discarded. Judicious combination of other levels reduced the total number of realistic combinations to the current number of 266. To test a crew's ability to perform all of these job objectives would be time-consuming, to say the least, and it must be remembered that these objectives cover only tank gunnery. Obviously, it is not feasible to measure job proficiency on all possible job objectives. Tests designed to measure effectiveness will be able to address only a limited number of the objectives. However, the need to select a limited subset of job objectives for testing is likely to produce unfortunate results. Training is almost certain to be concentrated on those areas which will be tested, to the detriment of other aspects of

[1] R.E. Kraemer, J.A. Boldovici, and G.G. Boycan, *Job objectives for M60A1AOS tank gunnery*, ARI Research Memorandum 76-9, Human Resources Research Organization, April 1976.

SLIDE 4

CONDITIONS AND LEVELS WITHIN CONDITIONS[a]

Conditions	Levels Within Conditions
Weapon	Main Gun
	Coaxial Machinegun
	Caliber .50 Machinegun
Fire Delivery Method	Battlesight (non-precision for machineguns)
	Precision
	Range Card
	Range Card Lay to Direct Fire
Firing Vehicle Motion	Stationary
	Moving
Target Visibility	Visible Without Artificial Light
	Visible With Artificial Light
	Not Visible
Target Range	<500 meters
	500-900 meters
	<900 meters
	<1100 meters
	1100-1600 meters
	500-3200 meters
	1100-2300 meters
	1100-3200 meters
	ALL

[a]Condensed from Fig. 2, page 2, R.E. Kraemer, J.A. Boldovici, and G.G. Boycan, *Job objectives for M60A1AOS tank gunnery*, ARI Research Memorandum 76-9, Human Resources Research Organization, April 1976.

the job. This might be avoided by testing each crew on only a small sample of jobs from the total job realm. If no crew knew exactly which set of items they would receive, they could not slant their training to the tests. However, the development of test items for every aspect of the job would be expensive. Also, the resources necessary for testing all aspects of the job would be extensive. In short, it appears that we have too many tasks and too few resources.

Reliability. We can only hope that our MOE are valid; that is, that they are indicative of how our teams would perform in combat. However, we usually can estimate their reliability. We were surprised, therefore, to find that the reliability of Table VIII scores has apparently never been determined. The only data located which even bear on the subject are those reported by Baerman and Eaton.[1] They found a correlation of r = .68 between ratings of tank commander motivation and Table VIII scores. This

[1] V.P. Baerman and N.K. Eaton, "Crew assignment and training," *Armor*, January-February 1977, 50-53.

would indicate that the reliability of the Table VIII scores was at least 0.68. However, there were several differences between both the conduct and the scoring procedures employed by Baerman and Eaton and those typically employed. A major difference was that scoring of hits was based on a close-in, after-the-fact examination of the targets rather than by an observer riding the tank. These investigators found early in their research that the observer determinations of hits were subject to considerable error. Therefore, had the Table VIII scores been obtained in the usual manner, quite different results might have been obtained. My personal feeling is that the test/retest reliability of Table VIII scores derived as recommended in FM 17-12[1] would be unacceptably low.

Steinheiser and Snyder[2] pointed to another reliability-related problem with Table VIII. For example, assume that 70% is a passing score. Further assume that we test 100 crews whose "true" level of functioning is exactly 70%. By chance, 47 of these crews would score less than 70%, and therefore be misclassified as nonproficient. Similarly, 21% of the crews whose true level of functioning was only 60% would, by chance, be misclassified as proficient. Errors of misclassification could be reduced by increasing the length of the test to improve its reliability. However, increasing the length would also increase the resource requirements, and resources are extremely scarce at this point in our history.

To recapitulate, our evaluations of tank crews are currently based almost entirely on performance in Table VIII. Yet, Table VIII scores are of unknown but questionable reliability. Because of this nearly total reliance on Table VIII, it is imperative that its reliability be determined, and that every attempt be made to improve its reliability, either by changes in scoring procedures or modifications to the conduct of the test. However, to date, I have been unable to obtain the necessary support to conduct a reliability study.

I have not closely examined specific team evaluation procedures in any other context. Therefore, I have no idea whether other branches in the Army or other military services face similar problems, but I strongly suspect that they do.

Testing strategies. Two principal issues divide evaluators in their approaches to testing. These are the employment of (a) one- vs. two-sided test situations, and (b) process vs. outcome measurements.

One-sided vs. two-sided tests. In a one-sided test, such as Table VIII, the examinees face a relatively structured situation in which the sequence of events is relatively fixed. "Aggressor" forces, if present at all, are restricted to specific preplanned activities. In a two-sided test, aggressor forces must be present and typically have few limitations placed on their activities. The advocates of two-sided exercises stress the importance of realism, the opportunities for real-time decision-making, and the morale-boosting aspects of competition. They also point out that the inflexibility of one-sided tests makes them easy to train and practice for. Therefore, they feel such tests provide only poor indications of how the participants would actually perform in combat.

Those favoring the one-sided approach to evaluation point to the fact that repetition of the identical circumstances is virtually impossible in a two-sided test. Therefore, no two individuals or teams receive exactly the same test, making it impossible to set exact performance standards or to compare the performance of any two teams. I should point out that choosing the type of test is not always a problem, for the type of data required frequently determine the most suitable type. For example, if exact times are needed, such as the time to fire after line-of-sight to a target is achieved, a one-sided test should

[1] FM 17-12. *Tank gunnery*, HQ, Department of the Army, Washington, D.C., March 1977.

[2] F. Steinheiser, Jr., and C.W. Snyder, Jr. "Score quality issues related to individual and weapon crew criterion-referenced performance tests," presented at the Military Testing Association Conference, October 1976.

be employed. Knowledge of the exact moment the target appeared would be virtually impossible in a two-sided test. One-sided tests are also generally necessary if live-fire is required.

Two-sided exercises are considered essential when targets must be generated. For example, a two-sided exercise would be necessary if the MOE were to be the ratio of friendly to threat casualties.

Process vs. outcome measurements. Stated very simplistically, "process" measurements are concerned with an evaluation of all of the actions taken during an engagement, but are not particularly concerned with the final outcome. "Outcome" measurements are not concerned with the procedures involved or the progress of the engagement, but only in who wins and who loses.

Osborn[1] is an advocate of process measurement. He feels that to be useful, a test must be diagnostic. That is, it must provide information on exactly why a particular aspect of performance was successful or unsuccessful. Hammell, Gasteyer, and Pesch[2] state the case for process evaluations in discussing Advanced Officer (AO) tactics training as shown in the next slide. In other words, Hammell, et al. feel that process is the only important aspect of performance in training evaluations. A good decision or action may lead to a poor outcome, but the decision or action should be evaluated on its own merits, and not on the vagaries of future actions by an unpredictable enemy.

SLIDE 5

> . . . numerous alternative sequences of actions may exist, many of which may be equally plausible for attaining a specific objective. The sequence of actions employed by the AO contains a complex series of evaluations and action selections which are situation intended. The attainment of the ultimate objective *may often be irrelevant to the evaluation of the AO's performance. This hit or miss philosophy, although distinctly meaningful in the operational environment, is inadequate in the training situation.*[3],[4]

The case for outcome measurements can be stated rather simply. In an operational environment, commanders are more interested in friendly/enemy loss ratios, resources expended, and territory won or lost. The attainment of some set of predetermined mission-oriented goals among these dimensions is a much more meaningful measure of effectiveness to the field commander.

[1] W.C. Osborn. *Process versus product measures in performance testing*, Professional Paper 16-74, Human Resources Research Organization, Alexandria, Virginia, October 1974. (Based on paper for Military Testing Association Meeting, San Antonio, Texas, October 1973.)

[2] T.J. Hammell, C.E. Gasteyer, and A.J. Pesch. *Advanced officer tactics training device needs and performance measurement technique - Volume I*, TR:NAVTRAEQUIPCEN 72-C-0053-1, General Dynamics Corporation, Electric Boat Division, Groton, Connecticut, November 1973.

[3] *Ibid.*

[4] Italics added by author.

Perhaps you are wondering why I bring up these strategies in a paper dealing with problems. The situation as I see it is this: We need process evaluations for feedback to training managers, and we need outcome evaluations to meet the needs of field commanders. Yet, it is difficult to obtain process information from a two-sided test and even more difficult to obtain outcome information of the kind desired by commanders from a one-sided test. It is difficult enough to obtain resources for even one type of test, much less two. The problem is in finding a way to combine the best features of both types of tests without undue expenditure of scarce resources.

Resources. I have already mentioned the resource problem in passing several times. The military services are experiencing one of the longest and most severe periods of austerity in their recent history. Yet, as has been pointed out, adequate evaluations are quite demanding of resources. In less austere times, Baker and Cook[1] painstakingly constructed a "Tank Platoon Combat Readiness Check." The final checklist, including instruction to the examiner, was approximately 90 typewritten pages in length. The authors also pointed out that the entire evaluation took approximately 30 hours to administer and required the use of "aggressor" forces. At the present time, most commanders would consider the resources required for routine conduct of such an evaluation to be out of the question.

It seems obvious that we cannot develop adequate evaluation techniques for team performance unless additional resources can be found. While such is unlikely an absolute sense, the possibility of conserving resources for evaluations offers some hope. Simulation techniques, for example, are being employed for training with increasing frequency and with little apparent loss in training effectiveness. For example, Powers, McCluskey, and Haggard[2] trained four groups of tank gunners employing 100%, 66%, 33%, and 0% live-fire. There were no differences between the hit percentages of the four groups in a live-fire posttraining test. Therefore, it appears that considerable ammunition could have been saved with no loss in training effectiveness.

Whether through the use of simulation or by other means, it is our opinion that the problem is not whether we expend the resources, but rather, how we obtain the necessary resources. As MG Gorman has stated, we must be prepared to fight outnumbered against an enemy whose weaponry will be virtually equal to ours. To do so, we must be able to accurately evaluate our fighting teams, and take corrective actions to eliminate any deficiencies.

[1] R.A. Baker and J.G. Cook. *The development and* evaluation *of the tank platoon combat readiness check*, Research Memorandum, Human Resources Research Organization, Alexandria, Virginia, April 1963.

[2] T.R. Powers, M.R. McCluskey, and D.F. Haggard. *Determination of the contribution of live firing to weapons proficiency*, Final Report FR-CD(C)-75-1, Human Resources Research Organization, Alexandria, Virginia, March 1975.